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**SECTION IV. THE ORE REGION OF THE BALKAN PENINSULA
AND THE DINARIC MOUNTAINS**

Introduction

This volume deals with the ore deposits and the general regularities of their distribution on the Balkan peninsula in its widest interpretation and in the Dinaric mountain ranges, up to their connection with the ore region of the Alps at Ljubljana. The area covered is bounded by the Drava River, the Danube below the mouth of the Drava, the Black Sea, the Aegean Sea, and the Adriatic Sea. At the mouth of the Danube, the Dobrudja is included, while in the Aegean Sea the Island of Thasos, the Northern Sporades, the Cyclades and Crete have been included. For purposes of presenting a better over-all picture, this great area is divided into an Eastern and a Western part along the Vardar valley, which constitutes a tectonic divide of the first order.

The data given are based not only on the literature which has been used but also on valuable reports by experts on individual deposit areas, which have not yet been published. Above all, the general conclusions are entirely new, and likewise the appended large general maps.

For each of the two main parts a short geological summary is given, followed by a detailed compilation of the ore deposits, with emphasis on the nonferrous metals, but also including general remarks on the deposits of ferrous metals. This is followed, as the most important result of this work, by a discussion of the general, magmatic-tectonic regularities in the distribution of these deposits. As a summary, the most important findings in regard to these regularities are given here:

a. The Balkan peninsula west of the Vardar valley and the Dinaric Mountains.

The areas of the paleozoic calcareous slate core of East and West Bosnia and of the Vardar zone are marked by their particularly high ore content. The rich East Serbian deposits of Maidanpek and Bor are more isolated in location and could be considered rather as spurs

of the Sub-Balkan eruptive zone of the eastern part. The Pelagonian massif and the northwestern continuation of the Inner Dinaric depression are strikingly poor in ore content. In general, the areas of slight tectonic fracture are poor in ore deposit or contain none at all, while those with large and numerous lines of faults and the magma outcroppings connected with them are rich in metal. Four main metal regions can be distinguished:

1. The Vardar zone: This imbrication zone, tightly bordered by the Pelagonian massif and the Rhodope Mountains, is marked by long veins of ophiolites mostly of the Jurassic Period. They carry the liquid-magmatic chromite deposits, but also are the precursors of more or less acid and also basic eruptive rocks which again frequently created ore deposits. Obvious connections with main tectonic lines occur. At the eastern edge of the Vardar zone, an axial master fracture line can be followed from the Chalcidice via Stip and Trepcia to Zvornik in Bosnia. East of Mitrovica a northern branch runs via the Kopaonik Mountains to Avala, south of Belgrade. Fissure lines, mostly parallel to the main axis, also carry important ore formations, e.g., a northeastern fissure line with the deposits of Zletovo, Kratovo, Bujanovici, Slisane, and a western fissure line with the chromites of the Ljuboten massif near Skoplje. The tertiary lateral dislocations are of only minor economic importance, but notable for their connection with deposits (Alchar, Dudica, Tetovo). The anticlinal uplift of Cukali and the overlap of the Mardita cover in Albania are tectonically connected with them. The intersections of the above main zones of faults were the most favorable for the occurrence of massive deposits, e.g., Trepcia and Kopaonik lie within the range of linking of the great longitudinal faults, Srebrenica and Zajaca at the intersection of longitudinal and transverse dislocations. Apparently there once was a uniform original magma underneath the Vardar zone which supplied in succession the ophiolites, and then granitic and adnesitic-trachytic eruptive rocks. The basalts near Kuma Kumanovo probably represent the most recent effusion.

2. Central and Eastern Bosnia: This variegated metal region is made up predominantly of paleozoic slate mountains and calcareous slate complexes and is characterized by the intersecting of longitudinal and transverse structures. The most striking fault is the Sava fault or the Inner Dinaric Main Fault. It penetrates the paleozoic slate mountain range, trending to the northwest, at a point south of Sarajevo. In some places it carries important deposits, viz., the antimony deposits of Cernica, the gold quartz veins of Travnik, and the great iron ore deposits of Ljubija. To the northwest this fault can be followed via Karlovac and Ljubljana into the Alps (Villach, Moell valley, Hohe Tauern range). To the southeast, its continuation can be traced easily as far as Foca and Brskovo, but then it disappears into several rows of lateral zones. The Skumbi trough and the fault area of Laurion in Attica may be parts of these zones.

The southwestern border of the Central Bosnia slate mountains is formed by the fault of Voljevac, which runs parallel to the Inner Dinaric fault. It contains the deposits of Sinjako, Maskara, Fojnica, and Kresovo. It seems to be the carrier of the highest thermal ore formations in Bosnia. The intersection areas of longitudinal and transverse dislocations in Bosnia are the most common locations of important deposits (Ljubija, Varas, Fojnica, Kresovo). Here the ophiolites are probably from the Cretaceous or Postcretaceous Period, as distinguished from the Vardar zone, where they are of Jurassic origin. Most of the ore deposits, however, are Tertiary.

3. The East-Serbian part of the Sub-Balkan eruptive zone: The great andesite areas of Eastern Serbia, the magma of which are either Senonian or Tertiary (in two different phases), are already part of the continuation of the Sub-Balkan eruptive zone of Bulgaria. The pyrite deposit of Maidanpek is bound to the contact region between andesite and mesozoic limestones. The great copper deposits of Bor lie at the intersection of two main lines of fault. The gold quartz veins of the Delijovan seem to be post-volcanic phenomena of the andesitic eruptive rocks.

4. The pyrite deposits of the Albanian Mardita cover are post-Eocene to Miocene and may be genetically connected to tertiary ophiolites.

b. The Balkan peninsula east of the Vardar valley.

A general outline of the genetic conditions of the formation of deposits in the eastern half of the Balkan peninsula gains greatly in clarity and becomes more convincing if the total area is divided from southwest to northeast according to the following geological-tectonic units:

1. The Rhodope massif (including the Strandzha Mountains and the Island of Thasos)

2. The South Balkan eruptive zone
3. The folded Balkan Mountains
4. The autochthonous Balkan foothills
5. The North Bulgarian - Rumanian table
6. The Dobrudja

1. In comparison with the other units, the large number of lead-zinc ore deposits in the Rhodope Mountains is striking. Besides these, the most characteristic features are oxidic iron ores and some chromite deposits which are bound to ophiolites. In the most important mining regions, the greatest ore veins generally trend more or less to the north. There are few complete faults, but there are zones of tensional gashes with ramifying veins and fissure systems, of a type which might have been created in a "rahmen" pressing of the entire Rhodope massif. The cataclasts are usually recent (Tertiary), but very often their direction is determined by the direction of the folds of the crystalline shales, and they can frequently be recognised also in veins of Pre-Senonian and Senonian granites, syenites, andesites, and in recent thermal lines. In the eastern part of the Rhodope Mountains proper, in the transition area to the Strandzha Mountains, sigmoidal flexures and east-west transverse dislocations are found in great numbers, among them

great overthrusts (Zar Assen). The position in decomposed anticlinals and the condition of the adjacent rock is apparently more important for the concentration and the size of the lead-zinc veins than their distance from magma cores; however, copper ore deposits seem to be more closely bound to the visible areal eruptions. Most of the chromite ores are probably the oldest ore formations, insofar as they are not bound to more recent secondary thrusts of ophiolites. However, the majority of the ore deposits, such as the recent effusive deposits (andesites, rhyolites, dacites) are undoubtedly of post-Eocene origin, probably Miocene.

2. The characteristic deposits of the Sub-Balkan eruptive zone are copper pyrite and pyrite and some important manganese ore deposits. This zone probably never was a truly geosynclinal, but a peripheral depression in front of the Rhodope massif, which was deepened by downfaulting. It was probably subjected to the same tensions as the Rhodope massif, but its southern edge contains a chain of syenitic to granodioritic intrusions, running from west to east, which shows visible relations to some of the contact deposits. A definite fixing of the time of intrusion of these plutonites, whose most recent parts still have some Senonic andesites enclosed in them, would be a key to establishing the magmatic relations between intrusive and effusive rocks and ore deposits in the Eastern Balkan peninsula in general.

3. The folded Balkan Mountains are characterized by the local accumulation of various metals (with lead-zinc and copper ores predominating). This can perhaps be explained by ore formation cycles of different age, from the Variscian to the Tertiary, at the same location, or perhaps by closely adjacent zones of the same cycle or by telescoping effects. At any rate, the congestion within the former folded geosynclinal is demonstrated thereby. The extensive occurrence of calcareous geosynclinal sediments has favorably affected the metasomatic ore formations (Plahalnica, Iskrec). East-west transverse structures are

particularly marked, as shown by recent thermal lines. To this is added a peculiar dome formation around isolated anticlines, with aureole-like ore deposits, especially in the western part (Berkovica). Where the recent plutonites belonging to the transition period between Cretaceous and Tertiary Periods occur both within anticlines and outside of them, they have resulted in ore formations only within the anticlines.

4-6. As compared with the above-named geological-tectonic units, the autochthonous Balkan foothills, the North Bulgarian - Rumanian table, and the Dobrudja are poor in ore deposits or have none at all. The Variscan ridge fault of the Dobrudja with its Paleozoic pyrite deposits is probably the richest area of this whole region.

c. Comparisons with the Alps:

A comparison between the regularities of ore formation on the entire Balkan peninsula and in the Alps is of value for future prospecting. Such a comparison will be made at the end of this volume. Very far-reaching general agreements can be noted. In both regions, the majority of the important ore formations are of recent Tertiary age. The chromites of the Vardar zone, which are bound to Jurassic ophiolites, form an important exception. Many agreements, or similarities, can also be noted in regard to metal content and mineral paragenesis. These are the result of equal magmatic jointing products of common mother rocks and accumulate in fault zones which are either equal or penetrate both areas. The intersections at acute angles of great longitudinal faults or the crossing points of longitudinal and transverse dislocations are the preferred locations of great metal deposits, in the Dinaric Mountains and on the Balkan peninsula as well as in the Alps.

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